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Product-Service Systems across Life Cycle

An initial training program on Product-Service Systems and servitization for engineering students

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Abstract

Although Product-Service Systems (PSS) are recognized as a promising model in literature, they are still not widely implemented in companies, mainly due to cultural barriers. Education should play a major role in removing these barriers and fostering the diffusion and implementation of PSS. This paper focuses on engineering education for graduate students and presents an original training program that was built and implemented at the Ecole des Mines de Saint-Etienne (EMSE). The main characteristics of this program are (i) multidisciplinarity, in terms of mixing PSS engineering and managerial approaches, and (ii) mixing theory, case studies and the use of simulation, based on several educational tools. The program is assessed out of the gathering of students' perceptions, which contributed to elaborate on some requirements regarding teaching servitization and PSS based on experiential learning theory.

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Keywords: PSS; servitization; training; engineering students; simulation; experiential learning

1. Introduction

Product-Service Systems (PSS) are a promising model which is not however widely implemented [1]. PSS are indeed a quite recent business concept which brings significant corporate, cultural and regulatory challenges for companies. Cultural barriers seem of particular importance, from a provider as well as a customer point of view: generally speaking, providers need to embed a PSS culture within the organization, and customers have a lack of knowledge and understanding about PSS. The role of Higher Educational Institutions (HEI) in the diffusion of knowledge and know-how to companies is then underlined. Indeed, education should play a major role in removing the cultural barriers and fostering the diffusion and implementation of PSS [1]. Integrating PSS and servitization in their programs should be especially relevant for engineering schools, as they generally pay close attention to keep curricula and courses updated and in line with societal and business demands. It is therefore important to look for outstanding examples and best practices with respect to integrating PSS and servitization in engineering education. But, quite surprisingly, very little or in fact no literature exists on that topic.

In this paper, we focus on engineering students' education and present an original training program we have built and implemented at the Ecole des mines de Saint-Etienne (EMSE). EMSE is a French graduate engineering school (Grande Ecole) which trains "generalist engineers" for manager positions in all sectors of economic activities. The training program presented in this paper is an elective course offered to last year engineering students. The main characteristics of this program are (i) multidisciplinarity, in terms of mixing PSS

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engineering and managerial approaches, and (ii) mixing theory, case studies and the use of simulation based on several educational tools. The theoretical part of the program offers a general view on PSS and servitization goals and challenges for companies. Case studies are used to show both the wide range of possible PSS alternatives for companies and the challenges associated with a servitization strategy. The simulation focuses on potential financial benefits of PSS strategies, and aims at raising awareness of the decision complexity associated with PSS, among engineering students.

The remainder of this paper is structured as follows. First, based on the observation that servitization is restrained by cultural barriers; we underline the need for introducing servitization and PSS in HEI' training programs. We then present the program we have built and deployed during the year 2015-2016 at EMSE. Next, we present students' perceptions on this program that were gathered through a survey; and finally we discuss these results and provide some propositions regarding training on servitization and PSS based on the experiential learning theory.

2. Conceptual background

2.1. Cultural barriers to servitization

Cultural barriers to sertivization have been widely studied in literature. Institutional and socio-cultural contexts greatly influence the choice of business models by companies and the way new businesses are implemented. This in turn influences consumption patterns in society. These contexts are reflected in organisational culture of companies, as well as in the behaviour of customers [2]. A wider implementation of PSS is then impeded by cultural barriers that exist on both on provider and customer sides [1,2,3].

Cultural barriers on customers' side are mainly related to a lack of knowledge and understanding about PSS, which induces customer reluctance regarding PSS offers, because of the uncertainties and risks on costs, and responsibilities [1,2]. Literature focuses mainly on customers' cultural barriers in B2C context; however, based on authors' ground experience, these barriers also exist for customers in B2B relationships [4,5]. The main problem lies in the fact that customers are reluctant to give up on the dominant and well-established norm of ownership [1].

On providers' side, delivering PSS is quite different from delivering goods. Manufacturing companies which want to "servitize" and provide PSS have to adapt their organization and to develop a PSS culture within the organization. To do so, they need new competences and skills. For instance, they need to acquire new methods and tools for PSS design and assessment. This induces a strong need for training companies' employees and managers, and even for hiring additional personnel. Moreover, training and education of employees and managers were found to be positively associated with the success of service innovation projects in manufacturing companies [6].

Servitizing manufacturers also face a resource constraint that is set by the education system: engineering education has mainly focused on the training of mechanical engineers and designers, despite the fact that servitization was acknowledged some 30 years ago. The engineering positions in today's industries require skilled engineers, both in product design and service design [7].

Educational background of employees and engineers is one of the most important cultural barriers, and education for PSS is needed in order to foster their wider implementation in future years.

2.2. Education for PSS

The literature review we have made shows that there are very little papers dedicated to education and training for PSS, and almost no papers that refer to existing programs in HEI. For instance, when we look at the last five IPS^2 conferences (from 2010 to 2015), we find only one session dedicated to "Knowledge generation, training and education" (in 2014).

Most of training devices that are mentioned in literature on PSS refer to in-company training. For instance, Nguyen et al. [8] present a method to introduce the PSS engineering into industry which encompasses teaching methods and tools in order to sensitize corporate management and train project managers and employees. The educational business game EDIPS (Edutainment for Designing Integrated Product-Service System) is more specially directed towards companies' designers [9]. Süße and Wilkens [10] propose a game-based learning scenario in order to "prepare individuals to PSS work environments", but they remain unclear regarding the targeted audience and evoke "employees in the engineering and the higher education sector".

We argue that if in-company training is essential to the diffusion of knowledge and practices on PSS, one should not forget that initial education is a key point as it eases the subsequent in-company training programs. In this regard, HEI can play a major role in reducing cultural barriers and diffusing knowledge and know-how to companies [1]. More specifically, the authors claim that teaching on servitization and PSS should be among the concerns of engineering schools.This leads to, at least, two key questions [1] relating to i) what knowledge and know-how should be provided to (engineering) students and ii) which educational approaches can best support the learning objectives?

The training program we decided to build for engineering students at EMSE answers these two questions in the following way: i) presenting a multidisciplinary overview on PSS and servitization; and ii) mixing theoretical lectures and more practical tutorials. This program is further presented below.

3. Training program presentation

3.1. Overview

The training program is an elective course for the last year graduate engineering students. The program has been taken by a group of 15 students. The program is 15 hours long, divided in 5 sessions of 3 hours, spread over 5 weeks, i.e. 3 hours a week during 5 weeks. Each session is divided into 2 parts: a lecture (1.5 hour) which aims at presenting general concepts;

and a tutorial, based on case studies and/or a simulator (1.5 hour). Table 1 presents the program structure and the content of each session.

Table 1. Training program overview.

Session	Title	Type
1	General introduction to the transition towards PSS	Lecture
	Application fields for PSS	Tutorial
2	Consequences on companies' business model and financial performance	Lecture
	Creating value from the steel sludge produced by metalworking industry	Tutorial
3	Servitization: a strategic transition for manufacturing companies	Lecture
	Economic simulations on value creation chains	Tutorial
4	Decision making for PSS Engineering	Lecture
	Multi-actor decision-making for PSS value network configuration	Tutorial
5	Environmental implications of PSS	Lecture
	Multi-actor decision-making for PSS value network configuration	Tutorial

Objectives and contents of both lectures and tutorials are presented thereafter.

3.2. Lectures

As a whole, the lectures aim at giving an overview on the numerous challenges which underpin PSS and servitization of manufacturing. The goal is to make the students aware of the need for a multidisciplinary approach to deal with these issues.

The first lecture is a general introduction, presenting main concepts and examples of PSS and servitization.

The second lecture focuses on servitization as a business model innovation for manufacturing companies. It consists in using the business model concept [11] to show the strategic and financial consequences of shifting to PSS.

The third lecture presents servitization as a progressive process for manufacturing companies (and especially SMEs) and a methodology to help decision-makers in designing the strategic and organizational transition.

The fourth lecture is oriented towards decision making for PSS engineering. The main goal is to make the students aware of the need of common tools for supporting the decision making in PSS design.

Finally, the fifth lecture focuses on environmental implications of PSS. PSS may be seen as means to cope with environmental concerns, and the lecture encompasses examples on typical environmental impacts of PSS and on methodologies that can be used to evaluate these impacts.

3.3. Turorials

Tutorials were built upon real case studies stemming from collaborative projects that the authors' research team has carried out in the recent years.

The first tutorial is based upon 3 different case studies of SMEs from the machine goods industry (B2B context) which planned to adopt a servitization strategy. The goal is to show the students that beyond the traditional and typical PSS examples (e.g. Xerox, Rolls-Royce, Michelin, etc.), servitization can also be a suitable strategy for SMEs in various fields. The tutorial is organized as follows. We first briefly present each case study: an overview of the company (e.g. products, possible existing services, etc.). Then, students (in groups of 3 or 4) choose one of the 3 case studies and are assumed to be customers, and then top management of the company. In the first situation they are asked to identify possible needs, requirements and usages of a future PSS offer, while in the second one, they are asked to provide a list of services that could be designed to meet the usages identified at the first situation.

The 4 other tutorials are based upon the same case study, which is about a French equipment provider who designs and manufactures an innovative machine that compacts the steel sludge produced by steel manufacturers to produce "steel-bricks". The sludge compacting enables collection of cutting fluid which can be re-used by steel manufacturers; steel bricks are made out of the residual steel which is hold in the sludge and can be sold to smelters as a raw material.

First tutorial is expected to allow the students seize the case study, as it will be used as a basis for the 3 following tutorials, and to become aware of (i) the variety of possible PSS solutions that can be designed around the same technical product; and (ii) the variety of the opportunities and risks the PSS solution entails for the stakeholders. Furthermore, the aim is to make the students aware of the usefulness of the scientific literature regarding PSS engineering methods and tools (e.g. Tukker's typology). During the first of these 4 tutorials, the case study is presented, and students are requested to work in groups of 3 to 4 on the identification of a PSS solution in the context of the case study. As a starting point of the students' analysis, we present Tukker's classification of PSS [12] (Fig. 1), and students are asked (i) to define and describe at least 2 PSS in 2 different categories of PSS, (ii) to assess the relevance of each PSS solution (main opportunities and risks) for each of the 3 stakeholders (equipment manufacturer, steel manufacturers, smelters), and to identify the possible environmental benefits of these PSS solutions. Finally, they are asked to determine the most suitable PSS solution for each PSS stakeholder.

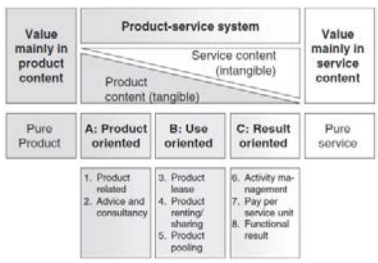

Fig. 1. Tukker's classification of PSS [12:248].

The 3 last tutorials are organized around the use of a simulator, which has originally been built in the framework of a research project [13,14]. These tutorials aim to develop a better understanding of the PSS organizational scenarios and the business models supporting them, through experiencing different decision making situations, using the simulator.

Second tutorial is concerned with the initiation into the simulator. The simulation is used to check the impact of different decisions on the economic performance of the PSS value network actors [13,14]. This tutorial is of much interest to the learning process as it makes the students familiar with the tool, prior to experiencing relatively complex decision making situations. The aim of the third tutorial is to make the students aware of the multi-actors perspective underlying the PSS. The students are asked to run simulations and to analyse the results for the various PSS network actors. Last tutorial is a follow up with the third one and aims to identify tradeoffs situations between the assessments of the scenarios for the different PSS network actors. Several PSS design teams are built and students are assigned to these teams as delegates of the PSS network actors. Then the students are asked to discuss together and using the simulator any possible tradeoffs that suits all the PSS actors. This tutorial illustrates the complexity of the decision making and pointes the importance of collaboration for a successful PSS implementation.

4. Student perceptions

In order to assess the overall program, we built a survey that we asked students to fill in at the end of the last tutorial. As only 15 students took this program, results should not been interpreted as statistically significant, but they provide at least useful elements regarding students' perceptions.

The survey items were developed around the key objectives of the lectures and tutorials. The survey contains 14 questions, grouped into 3 sections. First section includes a general question which aims at assessing the students' perception regarding the relevance of the overall program for engineering students. Second section includes 7 questions (2 to 8) relating to the lectures. This section aims to evaluate the efficiency of the program against learning PSS and servitization concepts. The last section includes 6 questions (9 to 14) which aim at assessing the relevance of the tutorials i.e. case studies and simulator. All the survey questions utilize a five-point Likert scale where 1 = Strongly disagree, 5 = Strongly agree and 3 = Neutral.

Table 2 shows the sample size, the average, and the standard deviations for each survey question. Scores range between 4.13 and 3.13, which means that generally most of the learning objectives are achieved even partly.

PSS and servitization prove to be attractive fields to the engineering students (Avg. 4.13), which can be explained by i) their possible experience as PSS end-customers, ii) the impact of the current PSS trend in the manufacturing sector on them, and iii) the consistency of this field with their background. This finding reinforces our belief that PSS and servitization should be taught in HEI and especially in engineering schools.

Other high scoring items include the understanding, based on the lectures, of the PSS and servitization concepts in general and as possible drivers for innovation and value creation. Surprisingly, students' perceptions are more positive and homogenous regarding lectures than tutorials. The average score for the items on lectures is 3.76 vs. 3.41 for the tutorials, and average standard deviation is lower for the lectures than for the tutorials (0.80 vs. 1.30).

Table 2. Survey sample size, average, and standard deviation.

	Items	Size	Avg	*SD*
1	PSS and servitization are innovative topics that need to be taught to engineering students (regarding their professional lives).	15	4.13	0.52
2	The lectures helped me to understand the PSS and servitization concepts.	15	4.07	0.59
3	The lectures helped me to understand that PSS and servitization are multidisciplinary concepts.	15	3.80	1.01
4	The lectures helped me to understand that PSS are possible drivers for innovation and value creation.	15	4.07	0.70
5	The lectures helped me to identify the challenges (including financial ones) that PSS entail for manufacturing companies.	15	3.67	0.90
6	The lectures helped me to understand the servitization process of manufacturing companies.	15	3.60	0.63
7	The lectures helped me to be aware of 1) the need for a decision making support in PSS engineering and 2) common tools used to support the decision making in PSS design.	15	3.53	0.83
8	The course helped me to be aware of the environmental implications of PSS.	15	3.87	0.74
9	The case studies have helped me to better understand the PSS and servitization concepts.	15	3.47	1.51
10	The case studies helped me to realize the wide range of possible PSS for companies.	15	3.47	1.19
11	The case studies helped me to understand the different types of PSS.	15	3.13	1.19
12	The case studies helped me to identify the opportunities (including environmental benefits) and risks of a PSS strategy.	15	3.60	1.12
13	The simulator helped me to understand the performance drivers of PSS strategies.	15	3.27	1.44
14	The simulator helped me to become aware of the multi-actor perspective underpinning the PSS strategy.	14	3.50	1.34

The short time dedicated for filling out the questionnaires is likely to impact on the results reliability, in particular towards the end of the questionnaire. The analysis of the results indicated poor correlation between the answers to the questions (Table 3). There are even negative correlations, in particular between items from the second section (relating to the lectures). Unsurprisingly, the highest correlation (0.87) is identified between items 13 and 14 relating both the use of the simulator. The second highest correlation (0.78) is identified between the second item *The lectures helped me to understand the PSS and servitization concepts* (Avg. 4.07) and the seventh item *The course helped me to be aware of 1)* *the need for a decision making support in PSS engineering and 2) common tools used to support the decision making in PSS design* (Avg. 3.53).

Despite the above inconsistencies, the results still however provide good insights into the relevance of the PSS and servitization learning to engineering students.

Table 3. Items correlation

	It.1	It.2	It.3	It.4	It.5	It.6	It.7	It.8	It.9	It.10	It.11	It.12	It.13	It.14
It.1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
It.2	-0.26	1	0	0	0	0	0	0	0	0	0	0	0	0
It.3	0.46	0.02	1	0	0	0	0	0	0	0	0	0	0	0
It.4	0.37	0.5	0.12	1	0	0	0	0	0	0	0	0	0	0
It.5	0.1	0.58	0	0.6	1	0	0	0	0	0	0	0	0	0
It.6	-0.04	0.27	-0.13	0.06	0	1	0	0	0	0	0	0	0	0
It.7	-0.18	0.79	0.14	0.67	0.44	0.16	1	0	0	0	0	0	0	0
It.8	-0.14	0.35	-0.23	0.15	0.46	-0.12	0.12	1	0	0	0	0	0	0
It.9	0.37	0.28	0.67	0.17	0.07	0.14	0.24	-0.2	1	0	0	0	0	0
It.10	0.12	0.36	0.32	0.3	0.22	0.27	0.45	0.24	0.63	1	0	0	0	0
It.11	-0.15	0.59	0.32	0.07	0.18	0.17	0.36	0.35	0.48	0.56	1	0	0	0
It.12	-0.39	0.69	-0.08	0.22	0.21	0.36	0.47	0.36	0.37	0.63	0.58	1	0	0
It.13	-0.05	0.56	0.33	0.48	0.24	0.2	0.71	0.17	0.43	0.72	0.4	0.65	1	0
It.14	-0.18	0.54	0.4	0.43	0.19	0.09	0.6	0.2	0.29	0.51	0.37	0.7	0.87	1

In the following section, we use experiential learning theory in order to discuss these results and provide propositions to enhance the program.

5. Discussion based on experiential learning theory

Experiential learning theory (ELT) [15] considers experiential leaning as a relevant mean to enhance learning in higher education [16]. The process of learning from experience can be depicted through a recursive cycle of experiencing, reflecting, thinking, and acting (Fig. 2). More precisely, it rests upon dual dialectics of action/reflection and experience/abstraction [17]. Concrete Experience (CE) and Abstract Conceptualization (AC) enable to grasp experience, whereas Reflective Observation (RO) and Active Experimentation (AE) support the transformation of experience. The four stages complement each other and are necessary to the learning process. On the other side, learners can be characterized by learning styles. They describe individual preferences for employing a specific phase of the learning cycle, and are influenced by learners' personality type, educational specialization, career choice, and current job role and tasks. Four styles of learning have been defined in ELT: Diverging, Assimilating, Converging, and Accommodating [15].

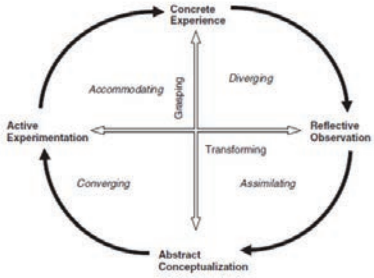

Fig. 2. The experiential learning cycle [15].

We propose to analyze the training program we have built according to ELT. Each session can then be considered as calling on mainly one of the four learning types (Fig. 3a and 3b).

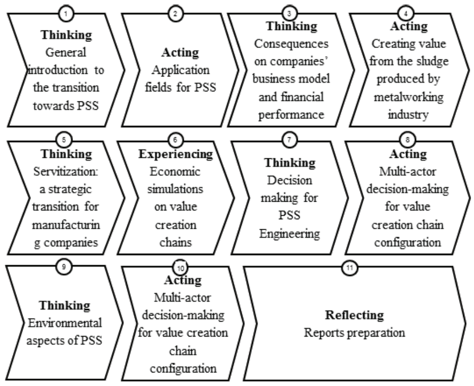

Fig. 3a. Training program analysis according to ELT.

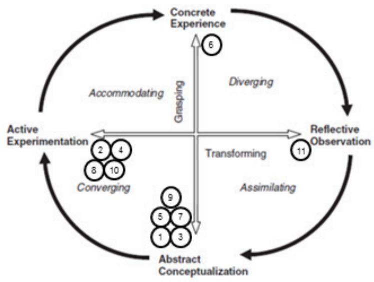

Fig. 3b. Training program analysis according to ELT.

When we insert the sessions on the learning cycle, we can observe that the PSS training program has mainly being based upon the AE and AC learning modes. Based on ELT, we can consider that the training program is more oriented towards the 'converging' learning style, which well suited for people who are "best at finding practical uses for ideas and theories […], have the ability to solve problems and make decisions based on finding solutions to questions or problems […] and prefer to deal with technical tasks and problems rather than with social issues and interpersonal issues" [17:46]. These learning skills are important for effectiveness in specialist and

technology careers, which is consistent with the profile of engineering students.
Nevertheless, ELT suggests that the basic learning styles (Diverging, Assimilating, Converging, and Accommodating) represent specialized and limited ways of learning, and introduces the concept of deep learning to describe the developmental process learning that fully integrates the four modes of the experiential learning cycle – experiencing, reflecting, thinking and acting [17].
Consequently, other learning modes, especially CE and RO are needed for consolidating the program towards a deeper learning process. For instance, CE can be fostered through direct experience, in-class experience, simulations, etc. whereas RO is supported by rhetorical questions in lecture, thought questions for reading, discussion, or brainstorming [17]. In this perspective, we now consider to introduce into the PSS training program the use of serious business games, and to call upon practitioners who could come into the classroom to share their field experience, receive students in their company, or even entrust students with PSS related projects.

The proposed training program still considers the students as receivers rather than actors, although the courses are concrete and practical. In this regard, improvement perspectives include the reinforcement of students' involvement and interactions with the instructors and between themselves.

6. Conclusion

HEI and especially engineering schools should play a role in the diffusion of knowledge and know-how on PSS and servitization, which is needed to foster their wider implementation. But the literature is particularly poor regarding examples and best practices with respect to integrating PSS and servitization in engineering education. In this paper, we have started to fill this gap through the presentation of a training program offered to last year engineering students at EMSE.

The results show that the content of the program has been acknowledged by the students as relevant in their curriculum, but some questions remain on the educational approaches that should be favoured. Moreover, our approach suffers from several limits: we could not used any qualitative analysis that could have enriched the results; only a post-questionnaire was submitted and we do not know the initial perception of students towards the contents of the course; due to the literature scarcity, we could not compare this program to other ones. Nevertheless, the program is very new; we aim at improving both the program design and its assessment on next academic year.

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